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RESEARCH ARTICLE

Vector Representation and Fibonacci Numbers in Molluscan Shells.

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Abstract

The present work describes the growth of a particular species of Molluscan shell in terms of moving vectors. The appearance of Fibonacci numbers in Molluscan shell has been identified.

Introduction:-

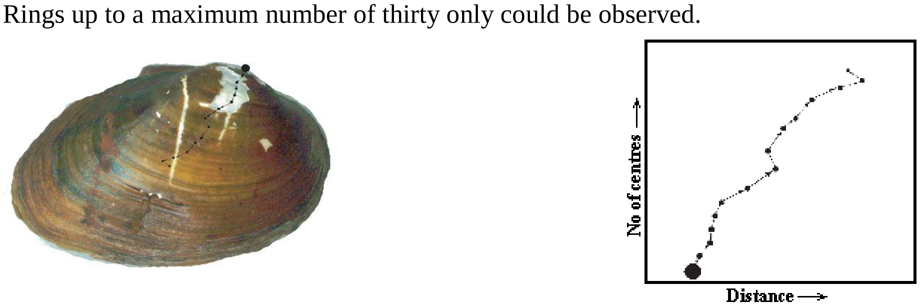
Molluscan shells have attracted the interest of research workers for many physical phenomena exhibited by the materials. The shells is created by a living pulsating creature around itself as a cover for defence and it represents some type of permanent phase which is irreversible. The materials of the molluscan shells present different appearances in different cases. The shell of a molluscan built out of calcium carbonate has 3000 times higher fracture resistance than crystals of calcium carbonate. Shell growth involves increase in both area and thickness. Increase in area is a function of increase of mantle and increase in thickness relates to the deposition of calcium carbonate and organic matrix. The reference points for all analysis of “bivalve” shell grows are the “unibones”; the oldest part of the shell. The majority of bivalves contain chromo-proteins associated with the conchiolin of their shell valves and many of the melaninoid pigments may owe their origin to the biochemical activities associated with the quinone tanning of conchiolin. Several decades ago Raman and coworkers[1-5] investigated experimentally various optical properties like iridescence and optical characters of shells. According to Raman [5] the external form of the shell and the internal architecture of its substance are intimately related to each other. While one may not know yet whether the beautiful patterns on the shell surface have a functional role, one is at present time at least able to explain how such patterns could arise. As in the case of Liesegang precipitation[6,7], it appears that certain non-linearities called into play during the shell growthare the controlling factors. Meinhart and Klingler[8] have succeeded simulating many of the observed shell patterns using a suitable non-linear reaction diffusion model. In bio-mineralization field, the mollusk shell is one of the best studied of all calcium carbonate bio-minerals. Particular attention has been given to organic matrix [9-13]. The organic matrixwhich promotes the nucleation of the mineral component to direct the crystal growth and is supposed to act as glue to prevent the fracture of the shell has been given particular attention [14-17]. The main biopolymers present in the organic matrix are essentially proteins, either glycosylated or acidic polysaccharides and chitin. In nacre they represent 1-5% (w/w)of the structure. The nacreous layer of Molluscan shell has been studied extensively for several decades particularly with X-ray and electron microscopic techniques. This work has been largely successful in describing microstructure of nacre [18-22]. Various calcium binding, highly acidic, water soluble proteins have been isolated from the shell in the various stages of development [23]. The process of purification and characterization of calcium binding conchiolin shell peptides from the Molluscan has been investigated by Cariolou and Morse [23] and also by others. Water soluble proteins from the shell have been characterized by X-ray diffraction leading to the conclusion that they resemble fibroin [24].

Both the water soluble and water insoluble proteins have been proposed as multilaminar templates for the mineral tablets [25]. The mechanism of growth of nacreous layer is complex and is not completely understood in spite of investigation of several decades. It is known that both organic and inorganic components are secreted by epithelial cells in the mantle tissue into the extrapallial space (the extra cellular cavity between the mantle and the shell which is sealed from the surrounding environment), bathing the growing shell in a mixture called the extrapallial fluid. It was Kitano and Hood [26] who first showed that aragonite is the most favorable phase of calcium carbonate ($CaCO_3$) to nucleate in sea water supersaturated with respect to that mineral. The submicroscopic structure of the conchiolin of the prisms in Molluscan shells has been extensively studied several decades ago by Gregoire [27,28]. It was established that the inorganic part of a prism is made up of calcite crystals piled one upon the other, the pile being wrapped into a conchiolin sheath built upon a fabrillar structure covered by a very dense protein component. The active role of proteins in biomineralization is a fundamental issue and has been described by several workers [29, 30]. It represents a source of inspiration for nanotechnology. The brick and mortar ordering of nacre (mother of pearl) has already inspired the toughening of ceramics materials by co processing rigid ceramics as silicon carbide and compliant interlayer as boron nitride [31]. The interdigitating brickwork array of tablets of sheet nacre is not only the only interesting aspects of nacre structure. The bio crystal itself is a composite. The spatial organization of the bio mineralization mechanism of the crystal growth is the main focus of the recent years [32]. Laser induced fluorescence spectra of few species of Molluscan shells were also recorded by Konwar et. Al. [33] and the salient features of the spectra were a strong diffuse band in the red yellow sector along with the persistent pair of band heads at 5407.1 Å and 5372.8 Å. These pairs of band heads appearing in the spectra are due to the First positive bands of molecular nitrogen.

We have indicated here a brief overview of the works and investigations carried out on Molluscan shells during last several decades. In the present work we shell consider the phenomenon of the evolution of the growth pattern of the shells and their representation in terms of vectors. The regular spacing of the external growth rings on shells and their progressive crowing as the Mollusks grow older continue to prompt researchers to interpret them as age makers, analogous to annual rings in some trees. Despite extensive study, however, the use of external growth patterns in most species has been found to be rather limited. In the present work we specifically discuss, for the first time, the appearance of Fibonacci numbers in Molluscan shells. This seems to be connected with the phenomenon of "Antisymmetry" which is seen as a part of biological evolution of plant and animal species [34].

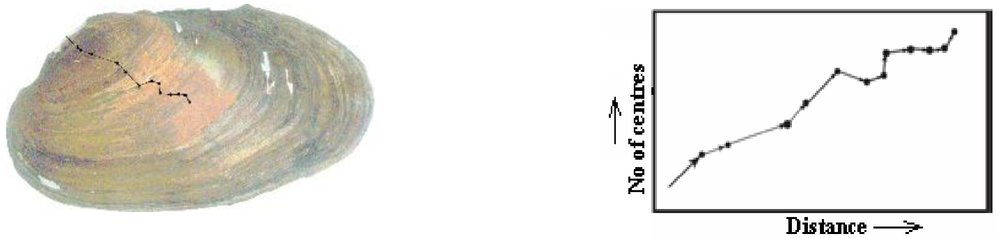
Evolution of elliptical patterns and Vector representation:-

The Molluscan shells which I have procured from *Maguri bill*, near Dibru Saikhowa National Park, Tinsukia, Assam was used as specimens for our work. Fig. 4.1 (a, b, c, d, e, f) shows the photographs of six specimens of Molluscan shells along with the growth patterns represented as moving vectors. The vectors are drawn by taking the centre of an ellipse as a starting point of a vector and connecting the successive centres of the ellipses. It is worthwhile to note that some sort of oscillatory pattern is maintained as these vectors evolve
in time. In some cases such as Fig 1(e), the oscillatory pattern is more apparent. Anyone who is experimentally familiar with the production of Liesegang rings in gelatin films and other allied phenomena might be tempted to believe that such periodic precipitates are analogous to the periodic growth of the elliptical patterns. In Molluscan shells exhibited in Fig 1 the individual rings are so crowded together that it is not possible to observe them separately. Rings up to a maximum number of thirty only could be observed.



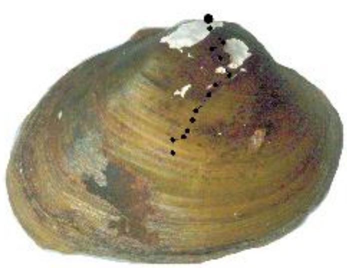
(a)

(b)

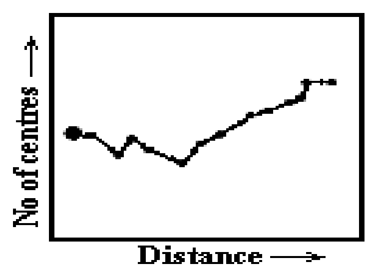


(c)

(d)



(e)



(e)

Fig 1 (a, b, c, d, e, f) Vector representation of the growth of Molluscan shells

Fibonacci Numbers in Molluscan Shells:-

The Fibonacci numbers are the sequence of numbers $\{F_n\}_{n=1}^{\infty}$ defined by the linear recurrence equation

$$F_n = F_{n-1} + F_{n-2} \quad \dots \dots \dots \dots \dots \dots \quad (1)$$

with $F_1 = F_2 = 1$. As a result of definition (1) it is convenient to define $F_o = 0$. The Fibonacci number for n = 1, 2, 3, ………… are 1, 1, 2, 3, 5, 8, 13, 21, 34, …………….. These numbers seems to appear in the Nature in numerous cases. It is worthwhile to note that the succeeding terms of the system are obtained by the sum of two preceding terms being with the lowest whole number; thus 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144 etc. This converging series of numbers is also known as a Fibonacci series, because it was first noted by Leonardo da Pisa, called Fibonacci. Gerard, a mathematician of the 17th century, also drew attention to this strange system of numbers because of its connection with the celebrated problem antiquity, namely, the eleventh proposition of the second book of Euclid. Its relation to the phenomenon of planet growth is brought out by Church[35], who uses a sunflower head to explain the phenomena.

Few other characteristic properties of Fibonacci series are that if we take three consecutive numbers, the square of the middle term and the difference between the multiplication of the first and third terms is always the same. Mathematically we have

$$F_{n-1} \times F_{n+1} - F_n^2 = (-1)^n \quad \dots \dots \dots \dots \dots \quad (2)$$

In Fibonacci series for any four consecutive terms (A, B, C, D), $C^2 - B^2 = A \times D$

For example in case of (2, 3, 5, 8)

$$5^2 - 3^2 = 8 \times 2, \quad 16$$

Mathematically we have

$$F_{n+2}^2 - F_{n-1}^2 = F_n \times F_{n+3} \quad \dots \dots \dots \dots \dots \dots \quad (3)$$

Any term in the series can be expressed by the equation

$$F_n = \frac{r_1^n - r_2^n}{r_1 - r_2} \quad \dots \dots \dots \dots \dots \dots \quad (4)$$

Here r_1 and r_2 is the root of the quadratic equation.

$$x^2 - x - 1 = 0, \quad \text{that is}$$

$$r_1 = \frac{1+\sqrt{5}}{2} \qquad \text{and} \qquad r_2 = \frac{1-\sqrt{5}}{2}$$

The closed form of (4.4) is therefore given by

$$F_n = \frac{\left(1+\sqrt{5}\right)^n - \left(1-\sqrt{5}\right)^n}{2^n\sqrt{5}} \quad \dots \dots \dots \dots \quad (5)$$

Again, leaving aside few small terms, if we take the ratio of two consecutive terms then the ratio always remain the same, and it is equal to 1.618. So the number is known as the divine number.

Fig1 shows the photographs of few specimens of shells. If we take the semi-major axes of the successive prominent elliptical rings we observe that the ratio of the distances (taken arbitrarily in millimeters) of the semi-major axes remains nearly constant and approaches the so called divine number as identical earlier(Table-1)

Table I

Ring No	Semi-major axis (in mm)	Ratio in successive rings	Difference from the divine number, 1.618
1	5	--	
2	8	1.600	+0.018
3	13	1.625	-0.007
4	21	1.615	+0.003

Summary and Conclusion:-

In the present work we introduce the concepts of moving vectors and Fibonacci numbers in naturally occurring Molluscan shells. It is reasonable to believe that the investigation will give additional insights into the secret of evolution of the Molluscan shell.

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